Keywords: Polyacrylamide hydrogel, pineapple leaf fiber, UV light, flexibility, tensile properties

Abstract. Pineapple leaf fibers (PALF) have several advantages such as low cost, eco-friendly, and high specific strength. However, the brittleness of PALF limits its application. To overcome this limitation of PALF, it is essential to synergize the advantages of PALF with elastic properties of hydrogel. In this study, PALF was coated with polyacrylamide (PAAm) hydrogel under direct UV light exposure (UVA>300nm). Prior to this coating, PALF was alkali treated to introduce more OH group on PALF fiber. The main purpose of this study was to investigate the effect of untreated/treated PALF coated PAAm hydrogel on the flexibility of the fiber using tensile measurements. From the results, treated PALF coated PAAm hydrogel showed better results in tensile properties compared to untreated PALF due to the alkali treatment which improved the interfacial adhesion between PAAm hydrogel and fiber surface. In general, this study is precursor for further development in natural fiber coating technology.

Introduction

In recent years, natural fibers including pineapple leaf fibers (PALF) have caught many researchers’ interests due to their potential applications and their promising properties as well [1-3]. Their viability and abundant in source appear as outstanding materials to replace expensive and non-renewable synthetic fibers. Like other natural fibers, PALF also offers its own remarkable properties such as high specific strength and high stiffness [4]. For instance, development of PALF has been vigorously studied for pulp and paper industries, textile industries and biomedical applications [5-8]. However, its inherent characteristics such as brittleness and poor elasticity limit the use of fibers unless further modifications are made.

Hydrogel or hydrophilic gel is cross-linked material that absorbs large quantities of water without dissolving it. Softness, smartness and the capacity to store water make hydrogel unique material that capture rising attention recently. Polymeric hydrogel networks may be formed by various techniques, however the most common synthetic route is the free-radical cross-linking copolymerization of a hydrophilic non-ionic monomer such as acrylamide (AAm) with a small amount of a cross-linker, e.g., N,N'-methylenebis(acrylamide) (MBAAm).

To extent the application of PALF in various commercial uses, it is interesting to synergize the favorable properties of PALF with polyacrylamide (PAAm) hydrogel behavior. In fact, there is no study regarding combining these two elements has been reported so far. In this study, we concentrated on the possibility of hydrogel coated on PALF to enhance the flexibility of PALF in terms of tensile properties measured.

Among several coating methods, the application of UV curable coating has been widely investigated due to its fast curing rate and energy-saving characteristic. Previously, numerous studies reported on radiation curing for hydrogels photopolymerization [9-11]. Hence, in the present
paper studied the effect of treated/untreated PALF prior to hydrogel coating on the tensile performance.

Experimental Section

Materials
Acrylamide and N,N’-methylenbisacrylamide were analytical grade and purchased from Acros Organic and Sigma Aldrich respectively. Photoinitiator used was benzophenone and other chemicals were used without further purification.

Alkaline treatment of PALF
Pre-dried fibers were soaked in 5 % (w/v) sodium hydroxide solution at ambient temperature. PALF were immersed in the solution for 24 hr. After treatment, PALF were plentifully washed with water to remove any traces of alkali on the fibers surface, before being neutralized with dilute acetic acid solution and were washed thoroughly with distilled water. Finally the treated fibers were dried in dryer at 60ºC.

Preparation of PALF-PAAm hydrogel coating
PAAm hydrogel was prepared by mixing 15% acrylamide (AAm) and 5% N,N’-methylenbisacrylamide (MBAAm) in 20 ml distilled water. PALF were weighed (0.25±0.02 gm) and soaked in PAAm hydrogel after been immersed in photoinitiator solution for one hour. Then, the wet PALF-PAAm hydrogel coating exposed to UV radiation for curing.

Characterizations
FTIR spectra of the PALF were recorded in the range 4000-370 cm⁻¹ using ATR apparatus at 4 cm⁻¹ resolution. Tensile properties were measured using Instron 3369 Universal Testing Machine (ASTM D3822) with 2.5 kN-load cell at 5 mm/min crosshead speed throughout the testing.

Results and discussion

Most commonly, alkaline treatment of fiber was to introduce more OH group for better results in interfacial adhesion. Figure 1 shows the FTIR spectra of PALF before and after alkaline treatment. The peak at 1730 cm⁻¹ and 1252.91 cm⁻¹ present in untreated PALF corresponded to hemicelluloses lignin. The peaks at 1730 cm⁻¹ can be attributed to the C=O valence vibration of acetyl or COOH groups. The peak at 1252.91 cm⁻¹ corresponded to C=O and C-O vibrations. The C=O group may also be present in the fiber as traces of fatty acids.

PALF consists of three main component: lignin, hemicellulose and cellulose. Lignin which is located at the outside layer of the fiber acts as an adhesive that holds cellulose fibrils together. After being treated, lignin was almost completely remove by Na in which a soluble sodium-lignin complex was formed [12]. As lignin was removed, hemicellulose content also reduced and cellulose fibrils were separated from the bundle to form small fibril fiber. The dissapearance of the peak 1252.91 cm⁻¹ in treated PALF spectrum indicated the removal of hemicelluloses region. This implies that hemicelluloses can be removed by acid hydrolysis. The peak at 3416.43 cm⁻¹ can be attributed to hydrogen bonded O-H stretching. The peak at around 2900 cm⁻¹ can be attributed to C-H stretching.
Table 1 depicts the tensile strength and elongation at break of the samples. The treated PALF-PAAm hydrogel sample exhibited high tensile strength (661.4 MPa) and elongation at break (3.74%). As anticipated, the tensile strength/elongation at break of untreated PALF-PAAm hydrogel possessed lower value. The increment of the tensile properties was attributed to the enhancement of the interfacial adhesion between fiber surface and the hydrogel. It is reported that fiber treatment has two effects: a) it increased surface roughness resulting in better mechanical interlocking, and b) it increased the amount of cellulose exposed and increased the number of possible reaction sites [13].

Not only that, better tensile properties demonstrated by PALF-PAAm hydrogel indicates that the hydrogel coating improved the PALF flexibility compared to uncoated PALF. Increasing value of elongation at break (3.40% to 3.74%) affirmed this affiliation since the PAAm networks stabilized and slightly hindered the deformation of the fiber. In short, it can be postulated that flexibility portrays by the hydrogel contributed to the trend. Further investigations and modifications are in progress to advance this combination to the fullest.

<table>
<thead>
<tr>
<th>Samples</th>
<th>Tensile strength (MPa)</th>
<th>Elongation at break (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated PALF</td>
<td>462.5</td>
<td>3.24</td>
</tr>
<tr>
<td>Untreated PALF-PAAm hydrogel</td>
<td>539.8</td>
<td>3.66</td>
</tr>
<tr>
<td>Treated PALF</td>
<td>499.9</td>
<td>3.40</td>
</tr>
<tr>
<td>Treated PALF-PAAm hydrogel</td>
<td>661.4</td>
<td>3.74</td>
</tr>
</tbody>
</table>

Figure 1 FTIR spectra of PALF before and after alkaline treatment
Conclusion

Polyacrylamide hydrogel coated PALF were prepared to modify the brittleness of PALF. Rather than poor adhesion of fiber and hydrogel surface, PALF was treated prior to coating which results in better tensile properties due to the enhancement of surface wettability. The tensile strength and elongation at break of the PALF increased after being coated with PAAm hydrogel. The improved flexibility of PALF by hydrogel coating can be further developed for natural fiber coating as well as new product development in textile and garment industries.

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References


